Context-dependent and dynamic effects of language distributional and sensorimotor measures on EEG

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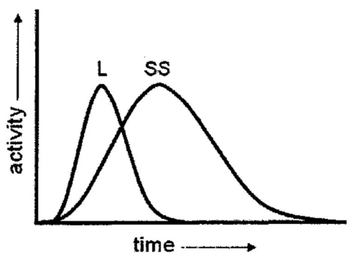
Introduction

What makes conceptual representations? Is experience-based sensorimotor information important? Or the language corpus-based distributional information?

A number of *hybrid* proposals argue that both sources of information contribute to our semantic knowledge (Davis & Yee, 2021).



Barsalou et al., 2008

The Language and Situated Simulation (LASS) theory (Barsalou et al., 2008) also suggests the linguistic associations will be prioritized in the first stage of semantic processing in relation to the perceptual information.

We operationalized distributional and sensorimotor information using cosine distance measurements derived from language corpus-based models and human sensorimotor judgments respectively, and examined how each is associated with the neural (EEG) and behavioral responses (RTs) to words in a property verification task.

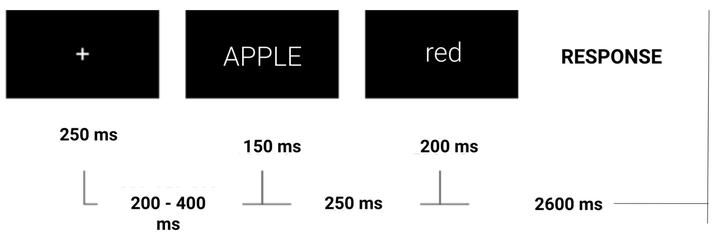
Exploiting the high temporal sensitivity of EEG, we compared the relative associations of both of our measures by modeling single trial voltages measured for every 100 ms.

Task

Property verification task:

Participants were presented with two words in a row. The concept (e.g., APPLE) was followed by the property (red), and participants' task was to verify whether the property (e.g., 'red') was typically true of that concept (e.g., 'APPLE').

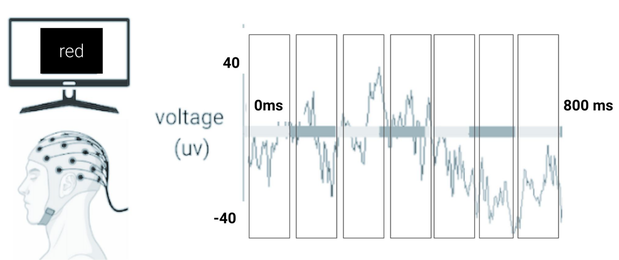
- 18 participants
- EEG was recorded using a cap with 29 electrode sites.

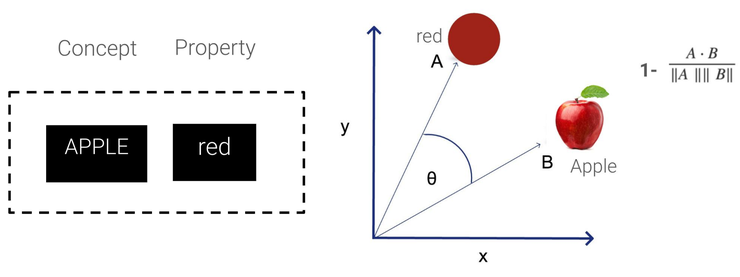


Analysis

Approach:

We constructed four competing LMER models for each of the 100-ms time windows for EEG (Winsler et al., 2018), and analogous models for RTs. TRUE and FALSE trials were modeled separately.





Measurements:

Single trial EEG, 100 ms averaged

Word Frequency: SUBTLEXus

Distributional Distance: GloVe 6B

Sensorimotor Distance: Lancaster Sensorimotor norms

Models and predictors:

Base model (B): Word Frequency

Distributional model (D): Base model + Distributional Distance

Sensorimotor model (S): Base model + Sensorimotor Distance

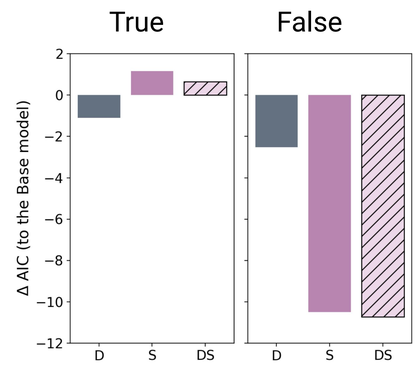
Distributional + Sensorimotor model (DS): Base model + Distributional Distance + Sensorimotor Distance

All predictors are z-scored and all models included subject and word level random intercepts. The Akaike Information Criterion (AIC) is used to evaluate the relative fit of the models, with ΔAIC of 10 as an indication of robust improvement (Burnham & Anderson, 2004).

Results

RT models:

Neither of the sensorimotor or distributional distances or word frequency reliably influenced the RTs for the TRUE ('Apple' - 'red') trials. However, sensorimotor distance fit best on the FALSE ('Apple' - 'black') trials and was observed to significantly speed RT by 23.44 ms ($p < 0.001$)

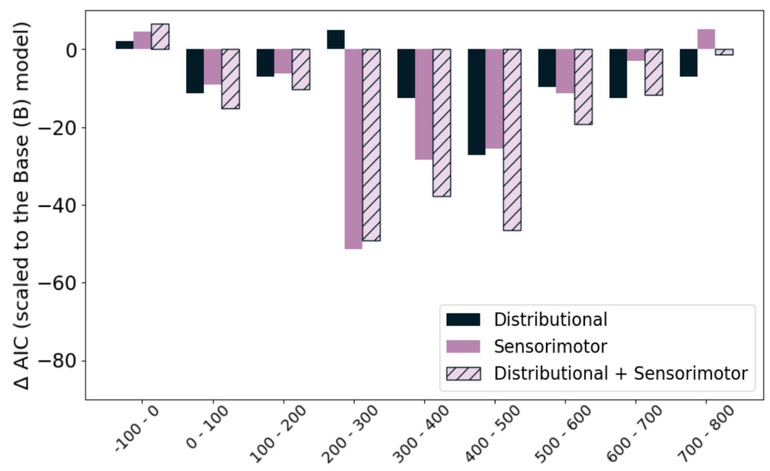


EEG models:

In 0-100 ms: The distributional model D robustly outperforms the Base model (ΔAIC > 10) for both TRUE and FALSE trials. For TRUE trials, the Sensorimotor model S also showed notable improvement from Base (ΔAIC = 9) .

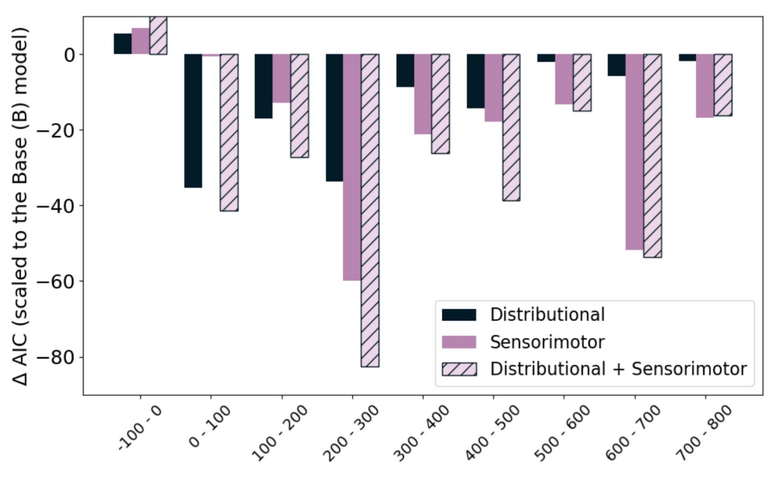
For TRUE: S model fits best from 200-400 ms, and then DS from 400-500 ms.
In 600-700 ms, D fits best.

a. True
(APPLE - red)



For FALSE: DS model fits best from 100-300 ms, S in 300-400 ms, and DS again 400- 500 ms. From 500-800 ms, S fits best.

b. False
(APPLE - black)



Discussion

- Consistent with hybrid models, distributional and sensorimotor information account for unique variance in the EEG and RTs suggesting property verification engages both.
- In keeping with dynamic models of semantic memory, the relative importance of both measures varies between true (APPLE- red) vs. false (APPLE- black) trials.
- As predicted by the LASS theory, distributional distance explains neural data in the earliest phase of semantic processing, but continues to predict EEG in later time windows as well.
- Overall findings support the emphasis on the contextual flexibility of semantic memory in *hybrid* accounts.

References

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